

## Polarized Raman spectroscopy on vertically aligned single-walled carbon nanotubes

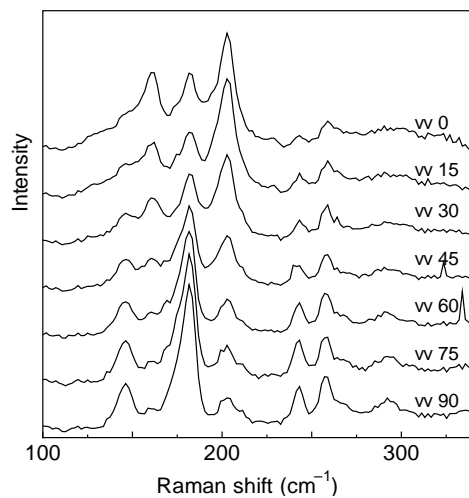
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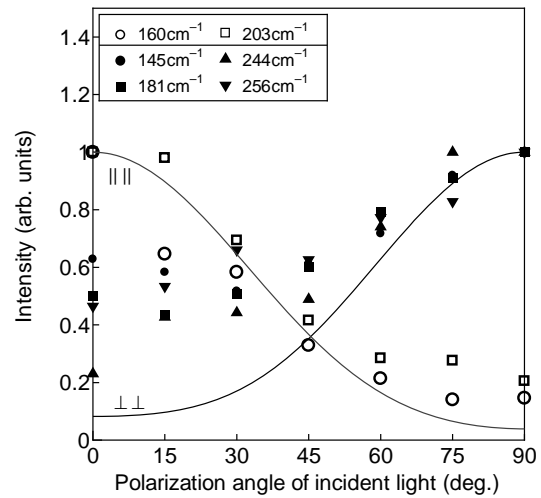
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Vertically aligned single-walled carbon nanotube (VA-SWNT) films with high purity have been prepared up to 30  $\mu\text{m}$  thick by the alcohol catalytic chemical vapor deposition (CVD) method[1][2]. In a previous polarized Raman spectroscopy study, we found anomalous anisotropic peaks such as at 180  $\text{cm}^{-1}$  for the excitation by 488 nm laser and explained them as perpendicularly polarized excitation [3]. However, recent high resolution Raman spectrum shows that the strong 180  $\text{cm}^{-1}$  peak is comprised by four fine sharp peaks which might be from isolated SWNTs. To clarify its origin, polarized Raman experiment is carried out using two configurations, where the orientation of the polarizer for inspecting the scattered light was parallel to (VV) and perpendicular to (VH) the polarization of the incident light. By changing the incident light orientation with respect to the VA-SWNT growth direction, two different polarization dependences were found for the radial breathing mode (RBM) peaks. The peaks at 160 and 203  $\text{cm}^{-1}$  behave consistently with the parallel excitation, while peaks at 145, 181, 244, and 256  $\text{cm}^{-1}$  exhibit the opposite behavior in the VV configuration. Although the selection rules for Raman scattering process allow perpendicularly polarized excitation in RBM (A mode) [4], 181 $\text{cm}^{-1}$  group peaks deviate much from the theoretical calculation assuming the orientation distribution by the order parameter obtained from absorption measurements[5]. The 181  $\text{cm}^{-1}$  group intensities were further revised by taking into account of laser heating effect, which show that they tend to be constant and independent for different polarization angles. Moreover, it is observed from high resolution SEM image that some isolated tubes distribute among the array which may correspond to the abnormal behaviors in CNTs.



**Fig. 1.** Raman spectra of a VA-SWNT film in the VV configuration, and changing the incident polarization from  $0^\circ$  (along alignment direction) to  $90^\circ$  (perpendicular to the alignment direction).



**Fig. 2.** Normalized RBM Peak intensity changes for incident light polarization from  $0^\circ$  to  $90^\circ$  with respect to the VA-SWNT growth direction (VV configuration).

## References

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